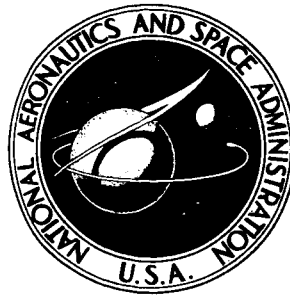


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**THE EFFECT OF BEDREST ON
VARIOUS PARAMETERS OF
PHYSIOLOGICAL FUNCTION**

PART V. DIETARY REQUIREMENTS

*by M. Walters, C. Vallbona, D. Cardus,
F. B. Vogt, and W. A. Spencer*

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Houston, Texas

for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FOREWORD

This study is a part of a NASA investigation of the effect of bedrest on various parameters of physiological function. It was sponsored by NASA Manned Spacecraft Center under Contract NAS-9-1461, with Dr. Lawrence F. Dietlein, Chief, Space Medicine Branch, serving as Technical Monitor.

This study was conducted in the Immobilization Study Unit of the Texas Institute for Rehabilitation and Research, The Texas Medical Center. The authors are affiliated with Baylor University College of Medicine as follows: Dr. Vallbona, Departments of Rehabilitation, Physiology, and Pediatrics; Dr. Spencer, Department of Rehabilitation; Dr. Vogt, Department of Rehabilitation; and Dr. Cardus, Departments of Rehabilitation and Physiology. Miss Walters is presently Nutritionist for the Texas Institute for Rehabilitation and Research and has served in the capacity of Research Dietitian and Research Committee Secretary.

The authors wish to express their appreciation to the medical and nursing staff of the Texas Institute for Rehabilitation and Research for their assistance in providing full time surveillance of the subjects during these experiments.

Credit is given also to Mrs. Carolyn Caldwell for her assistance in the preparation of this report.

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ABSTRACT

33542

This report presents data of the nutritional intake of thirteen subjects who participated in studies of the effect of short-term (3 days) and prolonged (14 days) bedrest. Two types of diets were used. One diet consisted of a 2 day cycle menu of fresh foods. The other consisted of three different menus of freeze-dried foods provided by the Food Research Division of the National Aeronautics and Space Administration.* This offset the advantages of easy preparation of the freeze-dried meals and the small storage requirements of the packaged foods. The composition of the diets in terms of caloric, calcium, and nitrogen contents remained nearly constant throughout the studies. Prolonged bedrest did not produce a significant change in weight, but bedrest accompanied with isometric exercises resulted in a loss of weight in the majority of the subjects. There was no evidence of constipating effect of the low-residue diet provided by the freeze-dried foods.

Spencer

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SUMMARY

In order to study the effects of immobilization on certain aspects of metabolic balance, it is desirable to provide a controlled diet which is (a) adequate in calories, calcium, phosphorus, and nitrogen, (b) of known composition, (c) well tolerated, and (d) low in residue. The latter factor is important in immobilization studies to avoid as much as possible the movement of the subject in performing emunctory functions. This report presents data of the nutritional intake of subjects who participated in a study of the effects of short-term (3 days) and prolonged (14 days) bedrest.

Two types of diets were used. One diet consisted of a 2 day cycle menu of fresh foods. The other consisted of three different menus of freeze-dried foods provided by the Food Research Division of the National Aeronautics and Space Administration.* This offset the advantages of easy preparation of the freeze-dried meals and the small storage requirements of the packed foods. The composition of the diets in terms of caloric cal-
cium, and nitrogen contents remained nearly constant throughout the studies. Prolonged bedrest did not produce a significant change in weight, but bedrest accompanied with isometric exercises resulted in a loss of weight in the majority of the subjects. There was no evidence of constipating effect of the low-residue diet provided by the freeze-dried foods.

INTRODUCTION

Numerous investigators have reported a disturbance in the metabolic balance of certain chemical elements as a result of prolonged bedrest.^{1,2,3,4} Increases in the urinary and fecal output of calcium, phosphorus, and nitrogen of immobilized subjects have been attributed to the decrease in activity of the musculoskeletal system.¹ In prolonged periods of immobilization, this loss can cause bone mineral depletion and alterations of the muscle mass.

* Freeze-dried foods were not as palatable to the subjects as fresh foods and some items were refused after the first time they were served.

It is desirable, in studying the effects of immobilization, to provide a controlled diet adequate in calories, calcium, phosphorus and nitrogen; of known composition; well tolerated; and low in residue. This report presents data of the nutritional intake of subjects who participated in short-term and prolonged bedrest studies. Although these studies were designed primarily to investigate the cardiovascular and musculoskeletal effects of bedrest, provisions were made to obtain data on the metabolic balance of calcium, phosphorus, and nitrogen. This report also includes descriptions of two types of diets presented; the average caloric, calcium, and nitrogen contents of the diets; and data relating to the acceptance of the menus by the subjects.

METHOD

A. Subjects

Thirteen healthy volunteers participated in the experiments. Six subjects took part in the first study which included a period of 3 days of bedrest and a second period of 3 days of bedrest during which the subjects performed isometric exercises in the horizontal position.

The second study was conducted with a new group of six subjects who remained in bed for a first period of 14 days. Five of these also participated in a second 14 day period of bedrest with isometric exercise. One additional subject was included in the second period as a replacement of a subject who requested dismissal after the first period.

The physical characteristics of the subjects who participated in both studies are presented in Tables I and II.

B. Experimental Conditions

The six subjects who participated in the first study of 3 days of bedrest (Study I) were admitted to the Immobilization Study Unit of the Texas Institute for Rehabilitation and Research on April 30, 1963, and were kept under observation for a period of 5 days. The subjects slept and had their meals in the hospital. Intake and output were carefully recorded. The subjects drank as much distilled water as they wished. After these days of observation, they remained in bed for 3 days, being allowed to move freely in the horizontal position. Meals were eaten in the horizontal position. Following the first period of bedrest, the subjects were kept under observation for an additional 3 days; they were on the same diet and the same conditions existed as before bedrest. The subjects were dismissed on May 11, 1963. They were readmitted on May 15, 1963, and kept under observation for 5 days; they were on the same diet as before the first period of bedrest. The subjects were weighed daily when ambulatory. A Toledo Precision Scale was used for weight measurement. The second period of bedrest, which also lasted 3 days had the same characteristics as the first period with the exception of a program of isometric exercises that were carried out in the horizontal position 4 times a day at 2 hour intervals. Following bedrest, the subjects were in the Study Unit for an additional 2 days of observation. Details of the experimental design of these studies are given in a separate report.⁵

TABLE I

Subject Number	Name	Age (years)	Height (cm.)	Weight before Bedrest (kg.)	Weight after Bedrest (kg.)	Change in Weight (kg.)	Weight before Exercise (kg.)	Weight after Exercise (kg.)	Change in Weight (kg.)
70-0-01	RKW	27	183.0	81.8	Not taken	Not determined	82.7	81.8	- .9
70-0-06	CBB	39	177.8	75.0	Not taken	Not determined	75.5	73.2	-2 .3
70-0-07	RNM	21	177.8	72.7	Not taken	Not determined	70.0	69.1	- .9
70-0-08	WRS	21	190.5	75.0	Not taken	Not determined	71.8	70.5	- 1 .3
70-0-09	THL	37	180.4	78.2	Not taken	Not determined	76.8	75.0	- 1 .8
70-0-10	RGW	40	175.2	76.8	Not taken	Not determined	78.8	77.3	- 1 .5
Average		31	180.8	76.6			75.9	74.5	- 1 .4

TABLE II

Subject Number	Name	Age (years)	Height (cm.)	Weight before Bedrest (kg.)	Weight after Bedrest (kg.)	Change in Weight (kg.)	Weight before Bedrest with Exercise (kg.)	Weight after Bedrest with Exercise (kg.)	Change in Weight (kg.)
70-0-11	ACL	33	170.3	62.2	62.5	+ .3	60.9	62.7	+ 1.8
70-0-12	TGO	21	188.0	73.4	72.9	- .5	DID NOT PARTICIPATE		
70-0-13	MGO	24	177.8	81.7	81.8	+ .1	79.8	78.4	- 1.4
70-0-14	DC	24	180.4	74.6	75.2	+ .6	75.8	75.4	- .4
70-0-16	CLB	24	185.5	82.6	82.7	+ .1	82.4	81.0	- 1.4
70-0-17	CP	34	180.4	78.2	77.7	- .5	79.0	77.7	- 1.3
70-0-18	ACI	22	165.0	DID NOT PARTICIPATE			50.7	50.9	+ .2
AVERAGE		26	178.2	75.5	75.5	0	71.4	71.0	- .4

The experimental conditions of the second study of 14 days of bedrest (Study II) were similar to those of the first (Study I) with the following exceptions. The subjects remained under observation for 7 days before bedrest and for 4 days after bedrest. The duration of bedrest was 14 days. The program of isometric exercises in the second period of Study II was carried out six times a day.

C. Dietary Intake Control

The diet provided during the first study (Study I) was a prepared 2 day cycle menu of natural fresh foods, which was calculated to provide 2400 calories, to contain 100 grams of protein (or its equivalent of 16 grams of nitrogen), to supply 1000 milligrams of calcium, and to be low in residue. The foods were prepared, weighed, and measured by the dietitian. Distilled water was used in the preparation of all food items as the calcium content of available natural water is high and variable. The subjects drank distilled water whenever desired.

Food preferences were taken into consideration in the preparation of the 2 day cycle menu, as it was important that all food presented be accepted. The subjects were informed of the importance of this part of the study and were instructed to eat all the food given. A sample tray of each prepared meal was taken to the laboratory for analysis. The 24-hour food intake was pooled and analyzed for (a) nitrogen by the Kjeldahl technique, (b) calcium by the Ferro and Ham technique (after ash drying), and (c) phosphate by the Fiske and Subba Row technique (after ash drying). In the event that a subject was unable to eat any given portion on the tray, the food left was taken to the laboratory for analysis, and the nutrient content of the portion left was deducted from the subject's total intake for the 24-hour period.

The same calculated and weighed diet was also used in Study II during the days when the subjects were ambulatory, on the days when glucose tolerance and lipid absorption tests were conducted during the first bedrest period, and on the last five days of bedrest with exercise period. The same methods of preparation were used and the same analysis was conducted by the laboratory.

During the bedrest periods of Study II, a diet of freeze-dried foods was used which was provided by the Food Research Division of the National Aeronautics and Space Administration. The purpose of using this food was to evaluate the practicality in its reconstitution, its acceptability and palatability, and its possible effect in reducing the frequency of bowel movements during immobilization. The 3 day cycle menu of freeze-dried foods was established by the Food Research Division. The menu had been used in other studies, and the caloric, calcium, and protein contents of the diet did not correspond exactly to those called for in the original experimental design. Food preferences could not be taken into consideration as in the calculated diet of fresh foods. Composition of the three menus, as analyzed by the manufacturer were as follows:

	Calories	Protein	Calcium
Menu I	2540	98.9 gm.	1240 mg.
Menu II	2543	106.4 gm.	1244 mg.
Menu III	2546	102.1 gm.	937 mg.

Individual servings of each freeze-dried food item were pre weighed by the manufacturer to a standard portion size and packaged in a polyethylene package which served as the container for reconstitution of each item. Distilled water was used for reconstitution. Final preparation of the food for serving was performed by the dietitian. Hot food items were reconstituted and then heated and kept at a constant temperature in a surgical sterilizer. Cold food items were reconstituted in advance of each meal and kept refrigerated until they were served.

An additional tray of the freeze-dried foods was not made for the clinical laboratory analysis, as only enough food for the subjects was supplied, and the foods had been previously analyzed by the manufacturer. Since the completion of the study, however, sample foods have been provided which the laboratory has analyzed. The values determined in this analysis were found to correspond with the analysis made by the manufacturer.

After the ninth day of bedrest during the second period of Study II, while the subjects were being fed the freeze-dried foods, food refusal increased and became a problem. The investigators decided to discontinue the use of the freeze-dried foods. From the tenth day of bedrest until the subjects were dismissed, therefore, the subjects were fed the same calculated and weighed diet of fresh foods as had been used in Study I. During the first period of Study II, on the second and third days prior to bedrest and on the twelfth and thirteenth days of bedrest, glucose tolerance and lipid absorption tests were made. The calculated, weighed diet of fresh foods was used on these days with the amounts of foods adjusted to meet the required values, taking into consideration the caloric and nutrient contents of the test solutions.

D. Psychological Tests

During the second period of bedrest of Study II, while the subjects were being fed the freeze-dried foods for the second time, one of the subjects (D.C.), a candidate for a master's degree in psychology, conducted a series of psychological rating tests in which all subjects participated. Every day each subject was asked to rate his personal attitude and his estimation of the attitude of each one of the other subjects. The following scale was used: Excellent - 5 points, Good - 4 points, Average - 3 points, Fair - 2 points, and Poor - 1 point. In addition, after each meal, each subject was asked to rate his own personal estimation of the meal according to the same scale.

RESULTS

A. Food Analysis

The average values of daily caloric intake (as calculated) and of calcium and nitrogen contents (as analyzed) are presented for Study I in Figure 1 and for Study II in Figure 2. The 3-day menu cycle of freeze-dried food is presented in Table III to document the foods used and to allow for reference and comparison for deviations from calculated amounts of the manufacturer.

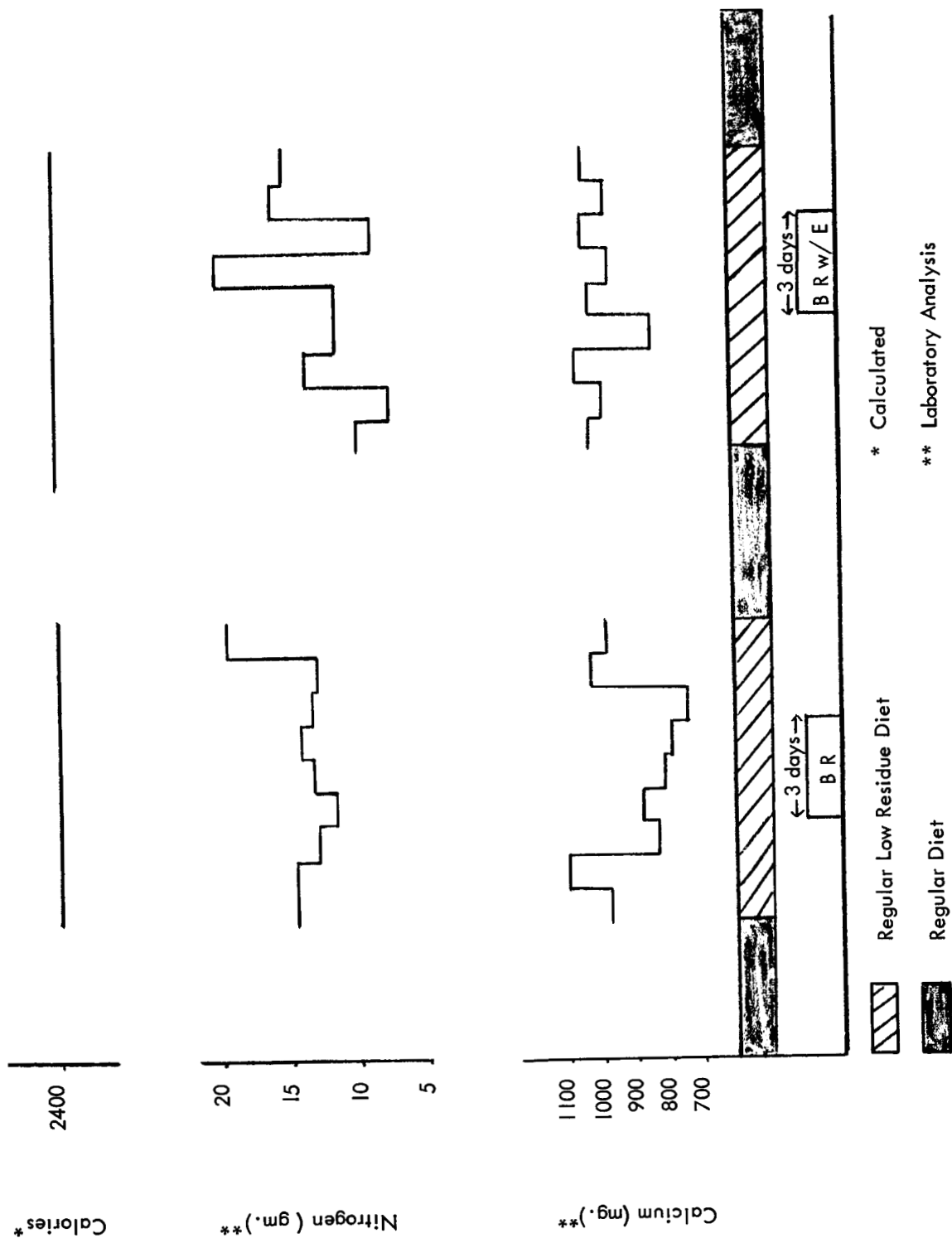


Figure 1. Dietary characteristics of Study I (3 days of bedrest and 3 days of bedrest with exercise).

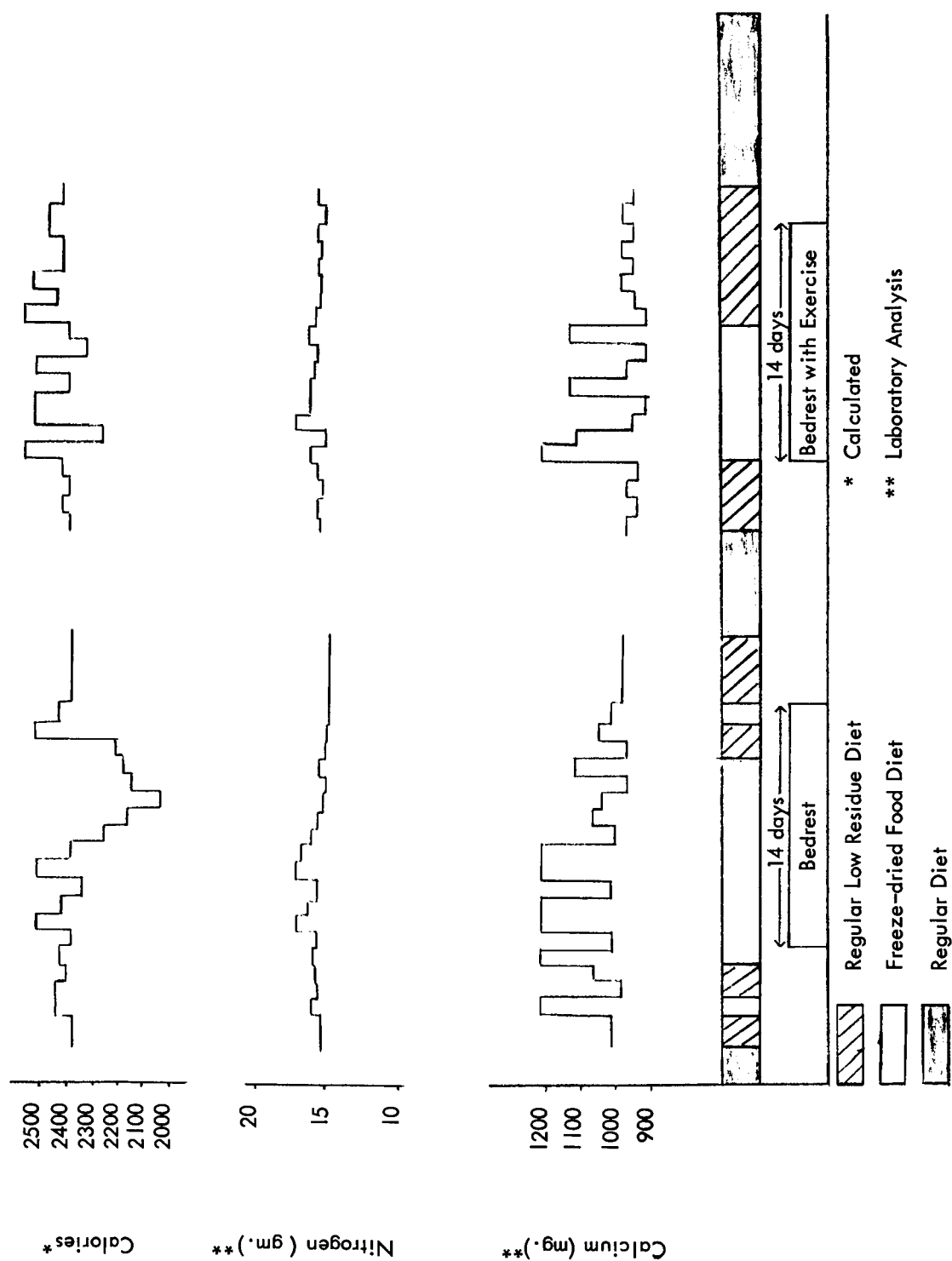


Figure 2. Dietary characteristics of Study II (14 days of bedrest and 14 days of bedrest with exercise).

TABLE III

THREE DAY MENU CYCLE OF FREEZE-DRIED FOOD DIET

MENU	BREAKFAST	DINNER	SUPPER
I	Orange Juice Beef Hash Cream of Wheat Cocoa Bread Jelly (2) Coffee, Cream, Sugar	Chicken with Gravy Sweet Potatoes Tomatoes Bread Jelly (2) Fruit Cake Coffee, Cream, Sugar	Shrimp Cocktail Pot Roast Whole Kernel Corn Rice Milk Bread Jelly (1) Coffee, Cream, Sugar
II	Strawberries Scrambled Eggs Oatmeal Milk Bread Jelly (2) Coffee, Cream, Sugar	Sliced Pork with Gravy Diced Potatoes Carrots in Cream Sauce Bread Jelly (1) Chocolate Pudding Coffee, Cream, Sugar	Grape Juice Beef with Vegetables Tuna Salad Green Beans Bread Jelly (2) Date Pudding Coffee, Cream, Sugar
III	Grapefruit Juice Bacon with Applesauce Cornflake Bar Cocoa Bread Jelly (2) Coffee, Cream, Sugar	Chicken with Vegetables Salmon Salad Potato Sticks Green Beans in Cream Sauce Bread Jelly (2) Fruit Cock tail Coffee, Cream, Sugar	Chicken Rice Soup Meat Balls with Gravy Instant Potatoes Peas Bread Jelly (2) Butterscotch Pudding Coffee, Cream, Sugar

On the tenth day of the first period of bedrest in Study II, the appetites of the subjects began to decrease. The decision was made by mutual agreement of the participating subjects and the investigators to eliminate the bread and jelly from the dinner and supper menus. This explains the decrease in caloric values presented in Figure 2. This change was not requested by the subjects during the second period of bedrest when the subjects did the isometric exercises.

The average daily fluid intake during Study I is presented in Figure 3 and in Figure 4 for Study II.

B. Effects on Fecal Excretion

The recording of the number of bowel movements of each subject throughout the two periods of Study II and the weighing of each stool permitted an evaluation of the effect of bedrest and the freeze-dried food on intestinal motility as indicated in the frequency of bowel movements. The data for each subject are presented in Figure 5.

C. Effects on the Subjects' Weights

The data of Tables I and II include the changes in weight that occurred in each subject throughout bedrest and bedrest with exercise periods in the two studies. The changes in weight in association with bedrest were evaluated in Study II only. It is clear from the data that there was no significant weight change during bedrest. In contrast, bedrest with exercise seemed to cause a significant decrease in weight in the two studies in spite of an over-all greater intake during the 14 days of bedrest with exercise than during the 14 days of bedrest without exercise.

The caloric intake of the subjects and the amount of physical exercise which they performed while on leave of absence between the bedrest and the bedrest with exercise periods of both studies were unknown and uncontrolled. The differences in weight after bedrest and weight before bedrest with exercise are attributed to these unknown factors.

D. Psychological Acceptance

Figure 6 presents the average of the subjects' attitudes as rated by themselves, with the average rating given for the three meals served on the corresponding day. The figures represent the first 9 days of bedrest with exercise while the subjects were on the freeze-dried foods and the last 5 days of bedrest with exercise after return to the weighed and calculated diet of fresh foods.

DISCUSSION

A. Food Analysis

The caloric content of the diet was maintained fairly constant throughout the two studies, except when it was purposely decreased on the ninth day of the first period

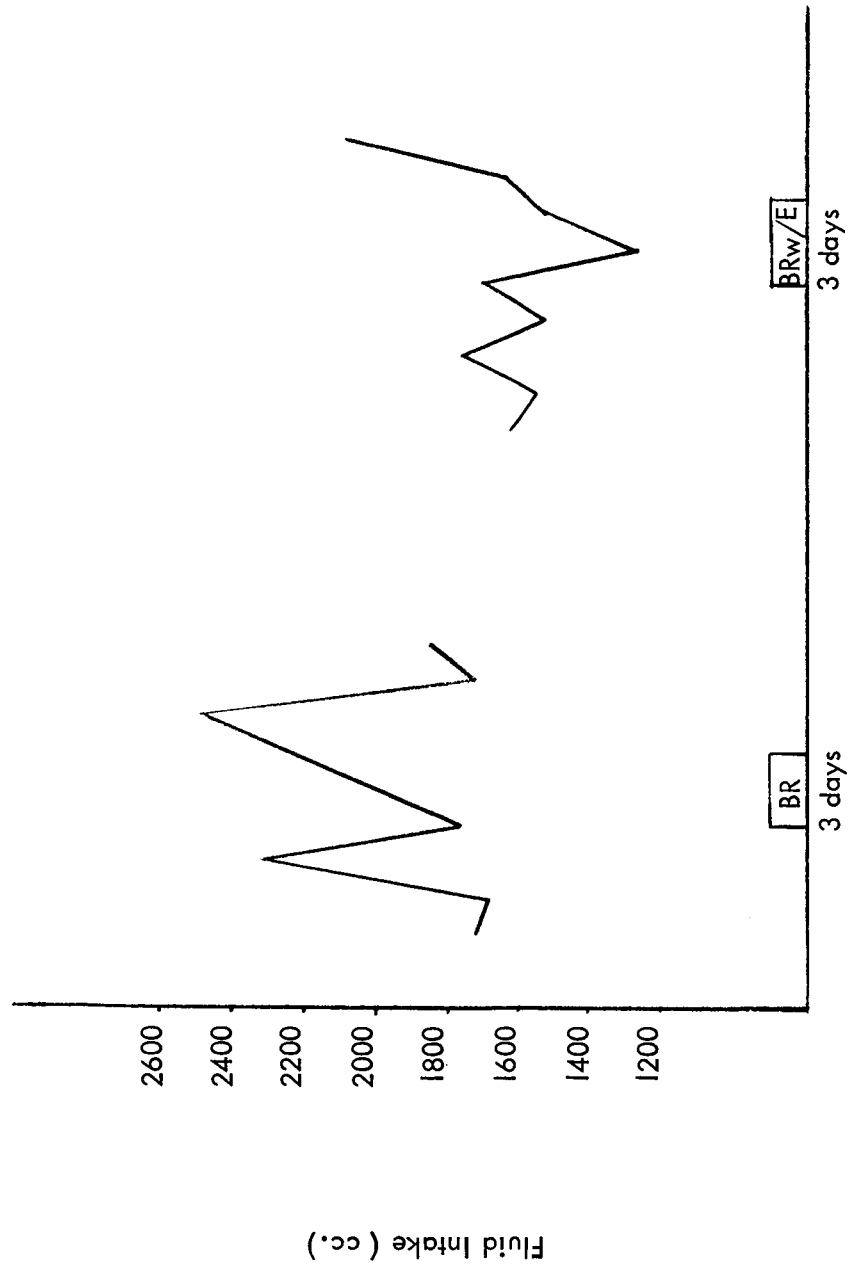


Figure 3. Average fluid intake of Study I (3 days of bedrest and 3 days of bedrest with exercise).

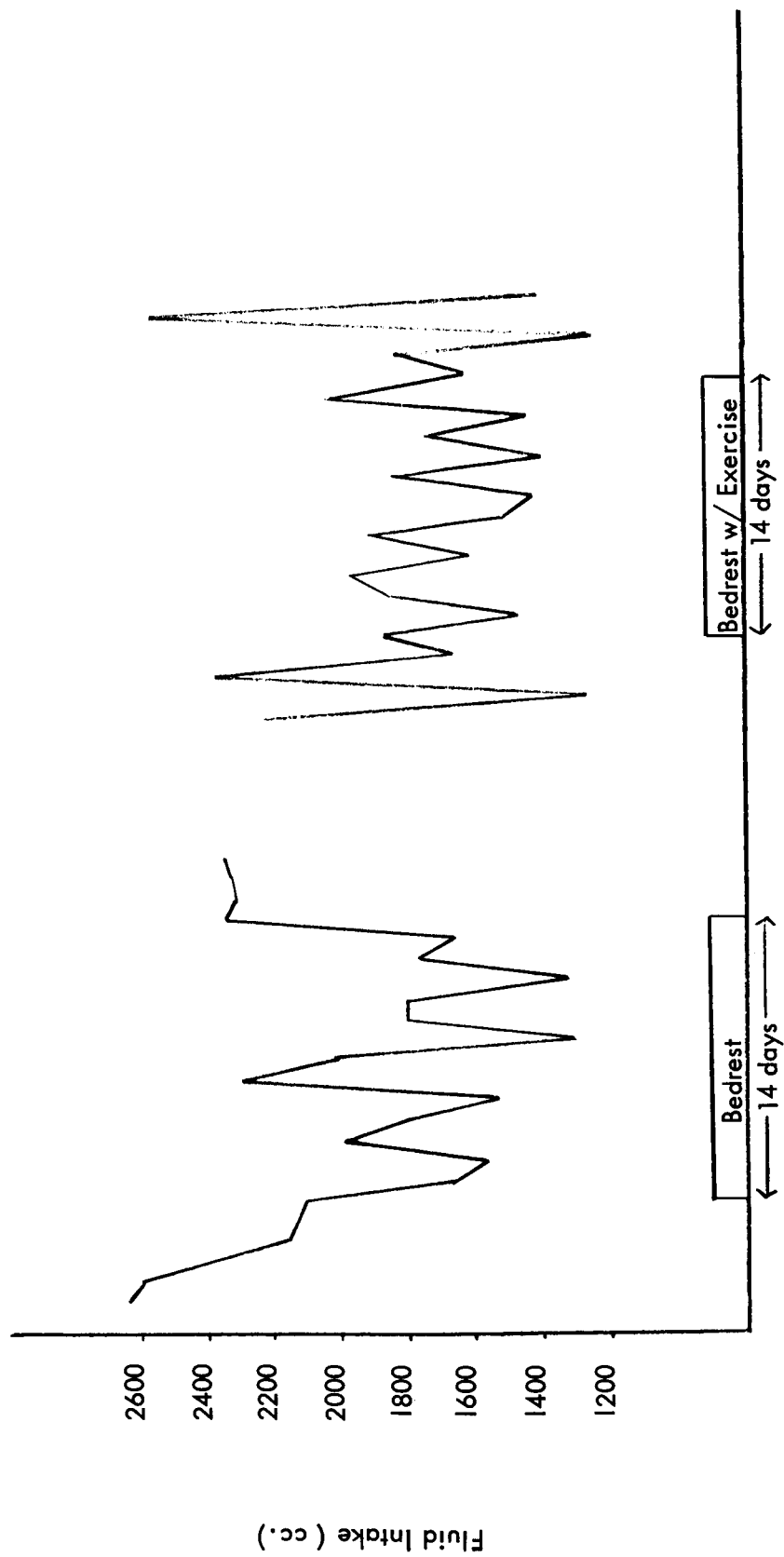


Figure 4. Average fluid intake of Study II (14 days of bedrest and 14 days of bedrest with exercise).

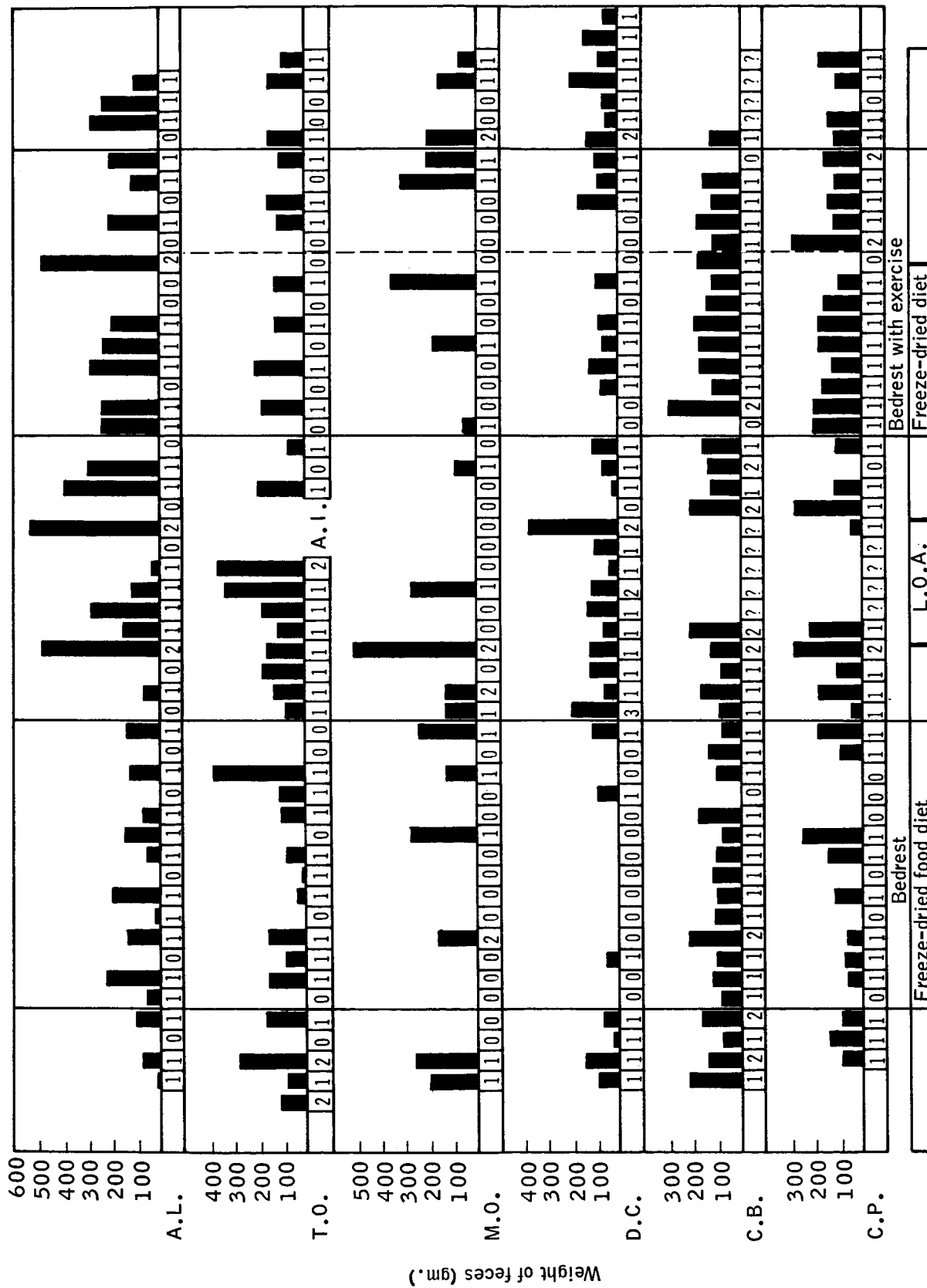


Figure 5. - Fecal frequency and bulk - study II (14 days of bedrest and 14 days of bedrest with exercise).

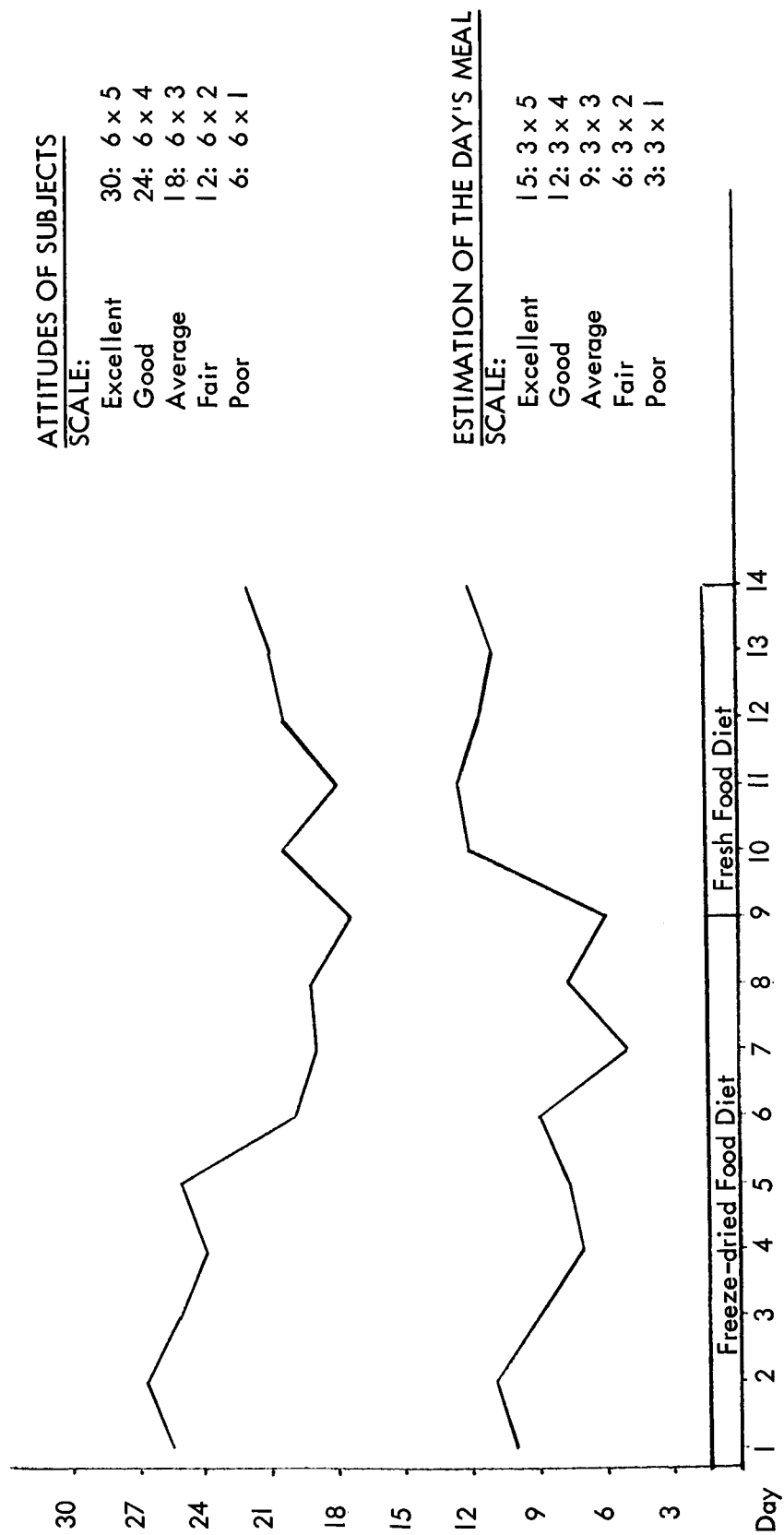


Figure 6. Attitude and meal rating scale - Study II (14 days bedrest with exercise).

of the second study (14 days of bedrest) because of a decrease in the subjects' appetites. It is likely that the caloric intake of 2400 calories was sufficient to compensate for the energy expenditures during bedrest. It is estimated that the basal caloric expenditure was 28 calories/kilogram⁶ and the expenditure caused by limited activity amounted to 3 calories/kilogram. This would represent a total of 2170 calories for a subject whose weight was 70 kilograms. It is estimated that during bedrest with exercise a caloric expenditure of 10 calories per kilogram was added to the basal caloric expenditure of 28 calories/kilogram. If this estimate is correct, the daily caloric expenditure during bedrest with exercise was 2660 calories for a 70 kilogram subject.

There were minor deviations in the nitrogen and calcium intake throughout each period of the studies. The deviations between calculated (16 gm. Nitrogen and 1000 mg. Calcium) and analyzed amounts of the weighed diet of fresh foods used had been expected because the nutrient content of foods given in the reference used for calculation⁷ is the average value of many samples. The marked deviation which is evidenced in Figure 1 was sufficient to justify reevaluation of the clinical laboratory technique of analysis. The technique was refined prior to Study II and there was better agreement with the results of the same samples submitted for analysis to two other laboratories.

Deviations from the manufacturer's analyzed amounts of the freeze-dried foods used during the bedrest periods of Study II are the result of food refusal of certain specific food items by the participating subjects. Foods refused by all subjects after they were served for the first time were the carrots in cream sauce and the powdered eggs. The subjects expressed objections to the taste and palatability of the products. An attempt was made to replace the nutrient content of these foods with the use of natural fresh foods which were analyzed by the laboratory.

The subjects objected to other food items contained in the menu of freeze-dried foods, but were encouraged by the dietitian to accept and eat the products. Encouragement was successful during the first period of bedrest, but during the second period it proved unsuccessful; the foods were refused upon presentation. These foods were sweet potatoes (refused by three subjects), tomatoes (refused by five subjects), beef hash (refused by two subjects), green beans in cream sauce (refused by six subjects), bacon and applesauce (refused by two subjects), and the cornflake bar (refused by two subjects). Individual reasons were given for refusal, but the major complaint was concerning the taste of the products. An attempt was made in the beginning to serve a food equivalent to that which had been refused, but as refusal became more constant, it became impossible to do so. Refused foods at this point were sent to the laboratory to be analyzed and the nutrient content of the portion was deducted from the individual subject's 24-hour nutrient intake.

Results and observations of this study pointed at severe deficiencies in the freeze-dried diet. Although the preparation of each meal was rapid and easy, the disadvantages arising from the poor palatability of the foods offset the advantages arising from easy preparation.

B. Effect on Fecal Excretion

The results as presented in Figure 5 do not give evidence that the combination of bedrest and the freeze-dried foods had a constipating effect. Subjects M.O. and D.C. had a considerable reduction in the number and bulk of their stools, but this effect was not noticeable in the other subjects. In general, the number and weight of the stools were greater during bedrest with exercise, the effect probably being due to the increased muscular activity rather than to the administration of a regular fresh food diet.

C. Effect on Subjects' Weights

The results of the study fail to show a decrease in weight during the 14 days of bedrest. A significant loss of weight had been reported in the study of Taylor et al.⁸ In the study reported by Dietrick et al.², no significant weight loss was noted. The discrepancies in the two studies have been interpreted by Taylor as due to differences in the caloric intake, since the subjects who participated in the study of Dietrick et al. were maintained on a relatively high caloric intake (2800 calories) in spite of their decreased mobility imposed by the restraint of the bi-valved casts. In all likelihood, the same explanation can be applied to this study, since the average caloric intake throughout the 14 days of bedrest was an average of 2400 calories, which is greater than normally required during inactivity. If this interpretation is correct, it may mean that a caloric intake greater than required offset whatever muscle catabolic activity took place during bedrest. By contrast, the decrease in weight that occurred in bedrest with exercise was probably due to the increased caloric expenditure during muscular activity.

D. Psychological Acceptance

As indicated previously, all the subjects agreed to cooperate with the dietitian and were, in the beginning, willing to accept and eat all of the food presented to them. It was clear, through, that this agreement could not overcome the problem of lack of palatability of some of the food presented. This problem may have influenced the deterioration in the subjects' attitudes as clearly shown in the psychological rating carried out by the subject D.C. It is necessary to point to the serious bias in this psychological rating since it was designed by one of the subjects who participated in the study and was carried out by each one of the subjects. The results have been presented not because there seems to be a correlation between the subjects' attitudes and the rating of the quality of the meals, but because they agree with the assessments of the subjects' cooperation as judged by the investigators and their assistants and as reported in the daily clinical observations entered throughout the study. The social worker who interviewed the subjects at the end of bedrest indicated that most of the subjects pointed out that acceptance of the freeze-dried foods was the major difficulty they encountered in the course of the experiment.

CONCLUSIONS

This report presents data of the nutritional intake of thirteen subjects who participated in studies of the effect of short-term (3 days) and prolonged (14 days) bedrest. Two types of diets were used. One diet consisted of a 2 day cycle menu of fresh foods.

The other consisted of three different menus of freeze-dried foods provided by the Food Research Division of the National Aeronautics and Space Administration.* This offset the advantages of easy preparation of the freeze-dried meals and the small storage requirements of the packed foods. The composition of the diets in terms of caloric, calcium, and nitrogen contents remained nearly constant throughout the studies. Prolonged bedrest did not produce a significant change in weight, but bedrest accompanied with isometric exercises resulted in a loss of weight in the majority of the subjects. There was no evidence of constipating effect of the low-residue diet provided by the freeze-dried foods.

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